BREEDING ECOLOGY OF THE BRONZEWINGED *(METOPIDIUS INDICUS)* AND PHEASANT-TAILED (*HYDROPHASIANUS CHIRURGUS*) JACANAS IN KEOLADEO NATIONAL PARK, BHARATPUR, RAJASTHAN[1]

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(With five text-figures)

Key words: *Metopidius indicus, Hydrophasianus chirurgus*, polyandry, dispersal, social subordination hypothesis and breeding behaviour

This paper analyses the breeding requirments of the Jacanas (Bronzewinged Jacana *Metopidius indicus* and the Pheasant-tailed Jacana *Hydrophasianus chirurgus*) in terms of biotic and abiotic factors, and describes some of the breeding behaviour. The study covered three breeding seasons from 1986 to 1988 in Keoladeo National Park, Bharatpur. The relationship between habitat and mating system of jacanas is examined. Both the species did not breed in large numbers in the same year; this difference is explained in terms of habitat requirements. The major abiotic factors determining the breeding season of both species of jacanas seem to be the timing and intensity of south-west monsoon, and the availability of water in the Park in a particular year. Among the biotic factors, availability of food and the presence of suitable habitat are equally important. At the end of the breeding season the adult to immature ratio of bronzewinged jacana was 36:22. The clutch size of pheasant-tailed varied from one to five. Clutch size of four had the highest frequency (0.62) followed by three (0.17). The dispersal of Bronzewinged Jacana is explained in the light of the social subordination hypotheses.

Introduction

Different aspects of breeding, especially on mating system of many species of jacanas have been reported earlier (Miller 1931, Hoffmann 1949, 1950; Mathew 1964, Dutton 1969, Jenni and Collier 1972, Steyn 1973, Vernon 1973, Wilson 1974, Osborne and Bourne 1977, Jenni and Betts 1978, Chattopadhyaya 1980, Osborne 1982, Fry 1983, Stephens 1984a, b). However, two species of jacanas occurring in the Indian subcontinent have not yet been investigated thoroughly in terms of their breeding habits and habitat, and their relation to the mating system. Mathew (1964) confirmed the existence of polyandry in the Bronzewinged Jacana (*Metopidius indicus*) but did not pursue further the various ecological reasons for polyandry.

The present study examines the breeding requirements of the Bronzewinged (*Metopidius indicus*) and Pheasant-tailed (*Hydrophasianus chirurgus*) Jacanas in terms of biotic and abiotic factors, and describes the breeding behaviour and the relationship of habitat and mating system.

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Study Area

The study was conducted in Keoladeo National Park, Bharatpur, a man-modified wetland situated in the Indogangetic plains at the confluence of the rivers Banganga and Gambir (27° 7.6' to 27° 12.2' N and 77°29.5' to 77°33.9' E) and at an average elevation of 174 msl. The Park has a boundary wall and is surrounded by agricultural fields and 18 villages. The total area of the Park is 29 sq. km. It is almost flat with a gentle slope towards the centre forming a depression of 8.5 sq. km. The aquatic area of the Park has been divided into various unequal compartments or blocks by means of dykes (Fig. 1). A metal topped road divides the Park lengthwise into two large blocks. On either side of the road, the wetland area is comparatively deeper than the rest of the area and holds water even in summer.

Bharatpur experiences extreme climatic conditions and during the study period temperature varied from 2.5°C to 45.33°C. The temperature showed seasonal fluctuation during the study period (Fig. 2). The lowest average temperature was in

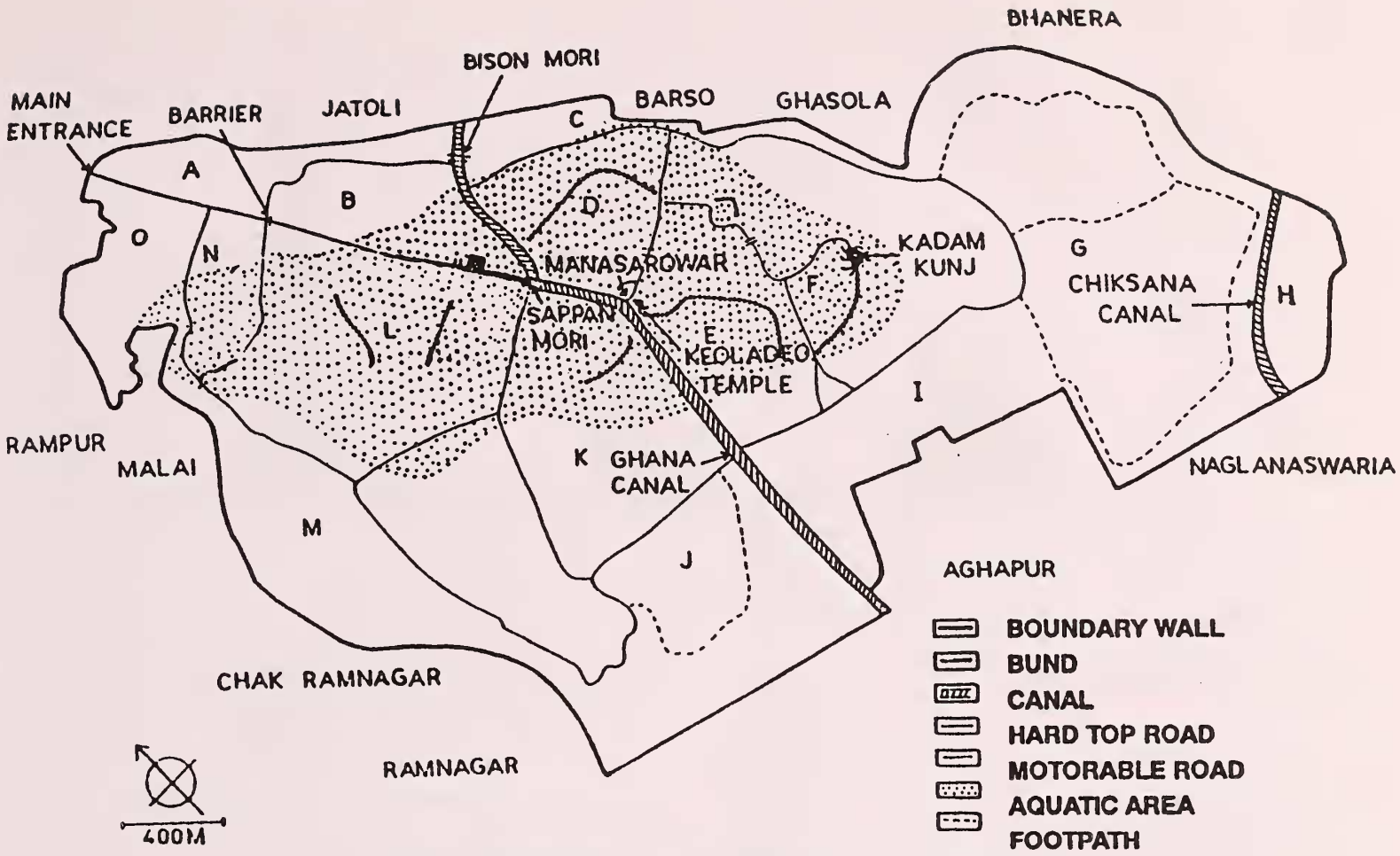

Fig. 1. Map of Keoladeo National Park, Bharatpur, Rajasthan.

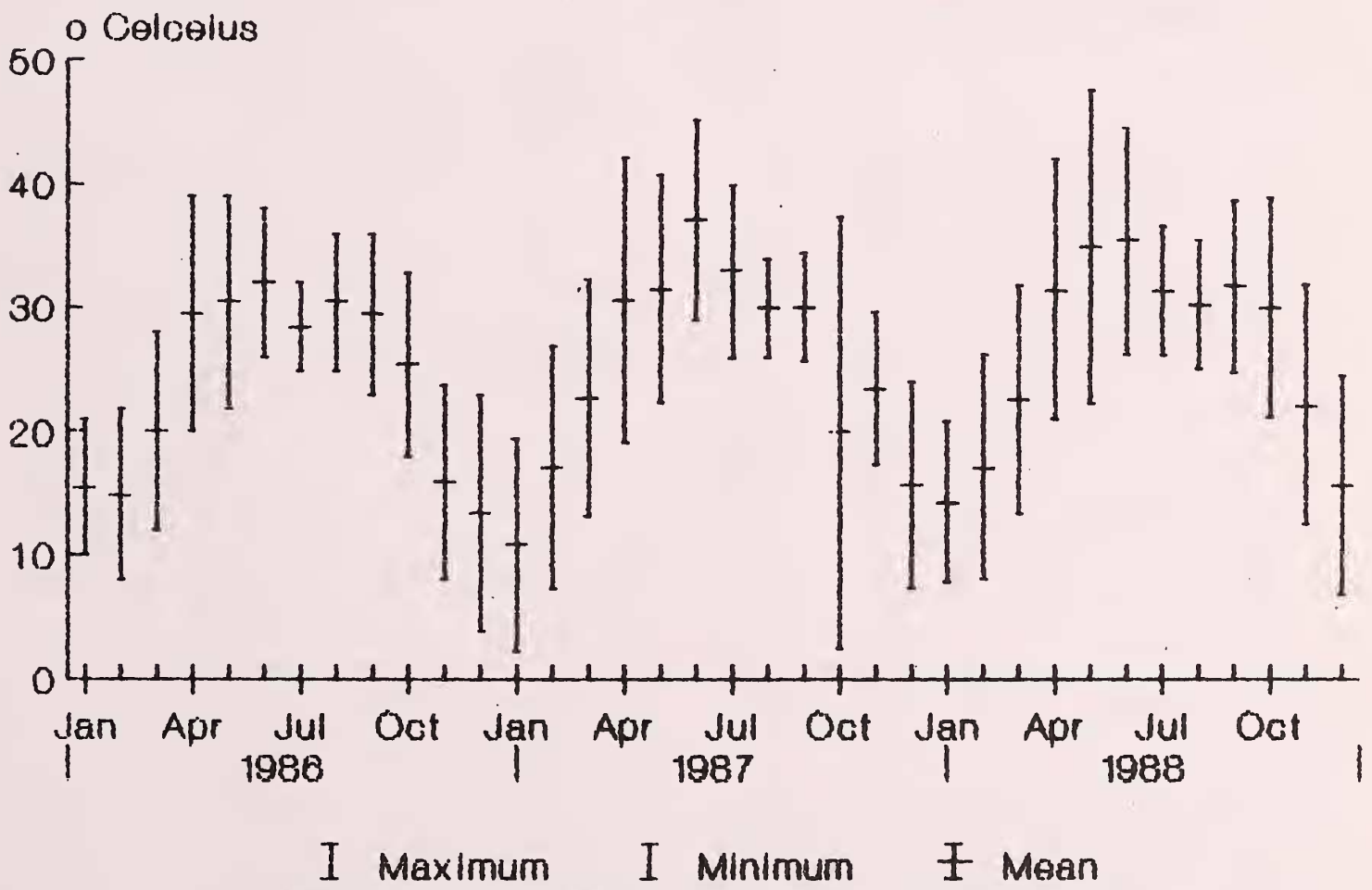

Fig. 2. Monthly variation of minimum, maximum and mean temperature in the park.

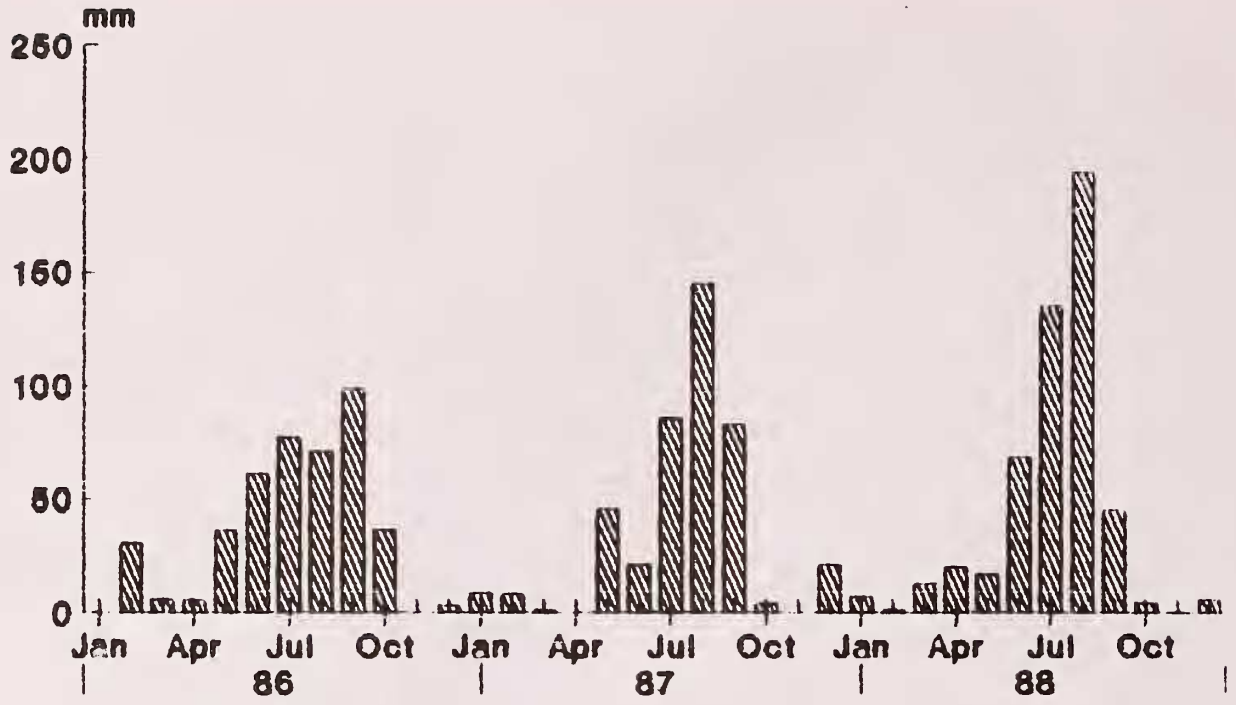

Fig. 3. Monthly variation of rainfall in the park from 1986 to 1988.

January 1987 and the highest in June of the same year.

The precipitation in Bharatpur is from the south-west monsoon which sets in by the end of June and continues up to September, sometimes extending to October. The total rainfall was 424.7, 423.4 and 614.2 mm during 1986, 1987 and 1988 respectively. The monthly rainfall varied from year to year (Fig. 3).

Water depth inside the Park showed characteristic monthly fluctuation (Fig. 4). During the study period the highest depths in each year recorded were in January 1986, October 1987 and August 1988. Water depth inside the Park increases as the water is released from Ajanbund, a reservoir situated away from the Park. There is an outflow in the initial stage; if the quantum of water received is large, a part of it is let off to the agricultural fields. Thereafter water losses occur only due to evaporation, percolation and evapotranspiration.

A detailed description of the topography, habitat, fauna and flora is given by Ali and Vijayan (1983), Vijayan (1988) and Prasad (1988, 1989).

Methods and Materials

Spot mapping (Kendeigh 1944) was employed to census the nesting jacanas following each family regularly after the onset of monsoon. When a nest was spotted the following parameters were recorded: (1) location, (2) nesting material, (3) plant species present in the immediate vicinity of the nest, (4) water depth at the nesting site, and (5) clutch size. If the chick had already fledged, they were counted and location was plotted on a map along with their parents. Morphometrics of eggs and the habitat quantification could be made only in the case of the Pheasant-tailed Jacana.

Habitat quantification was made by measuring the vegetation cover by the quadrat charting method of Mueller-Dombois and Ellenberg (1974). The quadrat (0.5 x 0.5 m) was divided into 100 columns by means of strings and all the plants in each column were identified and noted. Quadrats were placed at random. In the nesting site, stratified random sampling followed at 5 m intervals, on either side from the centre of the nest. Three samples, one each from either side and one from the centre of the nest were taken. These samples were subjected to clustering (Wilkinson 1988) using 1-Pearson correlation coefficient as the distance matrix to find out the similarity of nesting habitats.

Macroinvertebrate were sampled using a modified version of Wisconsin trap (Welch 1948). The macroinvertebrate taxa were identified up to orders in the case of aquatic insects only.

The data on the macroinvertebrate and

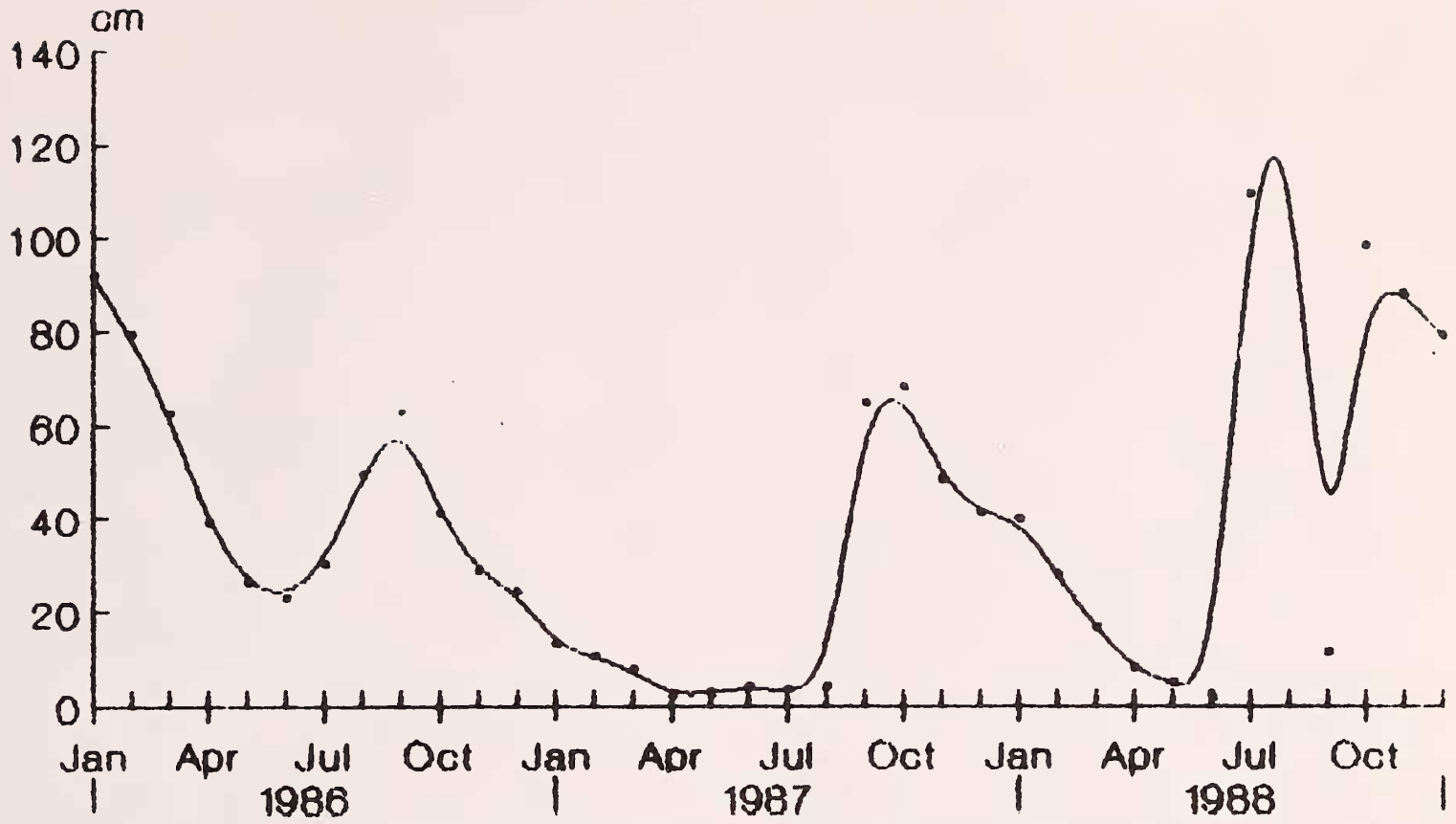

Fig. 4. Monthly variation of the water depth in the park from 1986 to 1987.

vegetation were compared between the feeding areas of the Bronzewinged and the Pheasant-tailed Jacanas using Mann-Witney U test (Wilkinson 1988).

Morphometric measurements of eggs were taken using vernier callipers. The length and width were measured at the highest points of the egg, obtained by sliding the callipers gently on the egg. The weight of the egg was measured using a Pesola spring balance of 30 g capacity.

Since colour marking of individuals was not permitted by the Forest Department in the study area, data on their mating system are circumstantial.

Results and Discussion

BRONZEWINGED JACANA

During the study period (1986-1987 to 1988-1989) Bronzewinged Jacana bred inside the Park in good numbers only during 1986-87. During 1988-89 only one pair bred in the study area.

Mating: Mating was observed only once in the Bronzewinged Jacana at 16.45 hr in July 1986. The female stood on an *Ipomoea* twig while the male approached her, and mounted quietly without any display. The act of copulation was accomplished within two minutes. While mounting, the male wriggled its body from side to side and flicked its tail up and down as if balancing itself on the top of the female. The female remained half crouched and motionless with its head stretched forwards. The male flapped its wings, when it was about to dismout. Once mating was over the male flew off and the female began feeding from the same area.

Nesting substrate and habitat: Out of the four nests located during 1986, two were on an *Eichhornia* patch and one each on *Ipomoea* and a float of decaying litter overgrown with grass. However in most cases, the habitat where chicks with parents were located had *Eichhornia crassipes, Ipomoea aquatica, Hydrilla verticillata* and *Ceratophyllum demersum.* An ideal breeding habitat of the Bronzewinged Jacana is formed by patches of *Eichhornia crassipes* or *Ipomoea aquatica* with other aquatic plants such as *Hydrilla verticillata* and *Ceratophyllum demersum.* When the nesting habitat had *Eichhornia crassipes,* the presence of grass patches (*Paspalum distichum*) was noticed nearby. The major function of *Ipomoea aquatica* and grass patches in their breeding habitat seems to be protection of their chicks from predators. This was evident from the behaviour of the bird: on hearing

the warning call from the male on the approach of a predator, usually the chicks hide themselves in these patches.

Territory: The territory size appears to be 50 x 50 m. The available mosaic of different vegetation patches inside the Park suggests that all other territories are of the same size as the one measured.

Nest: The nest was poorly built. Of the five nests with eggs discovered during the study (four in 1986 and one in 1988) two were on floats of grass (*Paspalum distichum*), one on an *Ipomoea aquatica* patch and another on an *Eichhornia crassipes* patch. The fifth one was sighted on a grass mat (*Paspalum distichum*). Three nests were lined with 3-4 twigs of *Hydrilla verticillata* and the rest had no lining.

Eggs: The morphometrics of only one clutch of three eggs could be obtained. The average length and breadth were 35.5 and 24.8 mm respectively. The eggs were glistening chocolate brown with black blotches all over them. The colour of the egg merged well with that of the substrate.

Clutch size: A total of 43 clutches were recorded by the end of September. Among these, five were as eggs and the rest had nestlings. Of the five clutches, two had three eggs each, and one each had one, two and four eggs. Three appears to be the highly probable clutch size as the families with three chicks were more in the breeding population of the Bronzewinged Jacana during 1986. The predation of clutch is not likely in this species as the nests were placed farther apart and hence the common predator, the marsh harrier *Circus aeruginosus* could not concentrate in certain areas and maximise predation as in the case of the Pheasant-tailed Jacana. Of the five clutches, the one with two eggs was preyed upon by a crow *Corvus splendens*. Two clutch size of four and three disappeared. The reason for the disappearance was not clear. Another clutch with a single egg was on an *Eichhornia crassipes* patch but was disturbed by the removal of *Eichhornia crassipes* by man. After the removal only a small patch of *Eichhornia* with the clutch remained. Still, the bird incubated it for 3 days. The egg was not seen subsequently but the bird was present in the same area. The prolonged disturbance by the *Eichhornia crassipes* collectors and destruction due to exposure of habitat around the nest, may have been the cause of failure.

Recruitment of chicks and dispersal: A total of 82 chicks by 38 individuals of the Bronzewinged Jacana were recruited into the population from June to September 1986 (Table 1). The population had lost 11 chicks by July end. After July it was not possible to keep track of each family as the chicks started dispersing and establishing their own group.

Several hypotheses have been put forward to explain the difference between dispersers and non-dispersers. Among these the social subordination hypothesis of Christain (1970) explains adequately the dispersal of the Bronzewinged Jacana. This hypothesis proposes that as the density increases, the resulting shortage of resources leads to increased levels of aggression, and this in turn forces social subordinates to disperse into sub-optimal habitats.

As the adult of the Bronzewinged invariably chased away juveniles of its own species, this could be considered as the consequence of congestion and resulting food shortage. The dispersal helps in regulating the population (Wynne-Edwards 1986) and inbreeding.

However, the population of the Bronzewinged Jacana became drastically reduced towards the end of September compared to that in June and July. The average adult to immature ratio of the Bronzewinged Jacana in September inside the Park was 36:22. The major reason for this fall was dispersal. Since none were noticed dead or caught by predators during the study period the mortality by predation and natural death may be playing only a secondary role.

Chicks: Two morphologically distinct stages can be distinguished in their development from chick to adult: the early stage when they are protected by parents and the later stage when they are free. The small chicks have light brownish downy feathers and two dark brown bands running from head to tail on the ventral side. At the immature stage they look almost like the non-breeding adult of the Pheasant-tailed Jacana. They do not have a white supercilium and the feathers are light brown. During this stage they are totally independent and feed in groups most

TABLE 1
RECRUITMENT AND MORTALITY OF CHICKS IN THE BRONZEWINGED JACANA DURING 1986

Recruitment	Blocks L west	L	B	D	E.	K	CANAL	Total
June	3	1,1,4	3,3	3	3,3,3,2	—	2	31
Early July	1	1,1,3	—	—	1,2	—	—	9
Late July	2,1	1,2,3,1	3	—	3,2,2,1	—	2	23
July Mortality	1	1	—	3	6	—	—	11
August	—	4,1,2	—	1	3	3	—	14
August Clutch	—	4	1	3	—	—	—	8
September	—	2	—	—	2	—	—	4
September Clutch	—	2	—	—	—	—	—	2
Total no. clutches	4	16	4	3	12	1	2	42
Total no. of Chicks	8	27	9	4	27	3	4	82

of the time.

Parent to chick relation: Although the chicks are precocial they always follow the male bird. The female bird stays nearby, within the territory feeding or helping the male in chasing away intruders and giving warning signals to the chicks of impending danger like the approach of predators. Parental care by the male includes brooding, attending and defending, but never feeding the chicks. The contribution of the female parent is insignificant compared to that of the male. The chicks feed themselves. These behaviour have been reported in the American Jacana *Jacana spinosa* also (Jenni and Collier 1972). The chicks left their parents once they attained the juvenile stage. The exact duration of staying with the parent is not known.

Antipredation tactics of chicks and parents: Two types of antipredation tactics were employed to protect the young: attacking the predator and distracting their attention. The major predator of the Bronzewinged Jacana is the marsh harrier *Circus aeruginosus*. The male bird with chicks usually fed inside the *Ipomoea aquatica* patch or grass patch. Whenever a raptor appeared overhead the parents, mostly the male produce a shrill alarm call, fly into the open water area of the breeding habitat and freeze. The chicks on hearing the warning, hide amidst the vegetaion. The behaviour of adult is the same even when unaccompanied by chicks. When an adult was attacked by a marsh harrier it countered by warding off the harrier with its legs and made the harrier to retreat.

Once a parent, when disturbed by the observer scooped up the chick in its wing and flew and landed 4-5 m away safely. This behaviour was reported earlier by Ali and Ripley (1983). Chick-carrying is also reported in the African jacana *Actophilornis africanus* (Hopcraft 1968).

On another occasion when a family of a Bronzewinged Jacana was chased by the observer and made to stay in an open area, the parents flew away making continuous shrill calls. The observer, reaching the spot, could not trace the chicks and hence moved away but continued watching the parents. On seeing the observer leaving the area the male parent uttered a feeble call and the chicks ran from the open area towards the male. Ali and Ripley (1983) reported that the bird can submerge itself in water keeping only the bill exposed; this must have happened in the above case also.

The gregarious habit of immature birds who, often form a group on being chased away by the respective parents, feed and roost together. This is probably an antipredatory behaviour.

During the initial period when the chicks are with them, the parents aggressively chased away

other species, namely Indian moorhen *Gallinula chloropus* and the immature individuals of Bronzewinged Jacanas, whenever they tried to trespass into the territory. Intrusion by immature Bronzewinged Jacana were not tolerated either in the initial period or later, when the chicks became independent. The moorhens were chased only when they tried to enter the *Ipomoea aquatica* patch where the chicks used to feed. Only the lesser whistling teal *Dendrocygna javanica* with its chicks was allowed to feed in the territory.

Polyandry: Jenni (1974) states that there are two radically different ways by which polyandry can function: (1) The males can cooperate with one another and share the role played by a single male in a monogamous system; (2) the behaviour of each male can be independent of other males and each male can interact with females as if the relationship were monogamous. Two species of jacanas, namely Pheasant-tailed (Hoffmann 1949, 1950) and Bronzewinged (Mathew 1964) occurring in the Indian subcontinent were reported to have all the points listed by Jenni for his second type of polyandry. However, Jenni in his review cast doubt on the typicality of polyandry in the Bronzewinged Jacana.

Through the present study evidences were gathered against typicality of polyandry in the Bronzewinged Jacana. The evidences mainly come from the study of their distribution during the breeding period. This study showed that each pair was widely separated, often by physical barriers such as dykes with trees. Furthermore, each pair was sighted almost always in the same area throughout the breeding season and beyond (July to January). This shows that the Bronzewinged Jacana in Keoladeo National Park was not polyandrous during 1985-86. Another point against polyandry is their non-gregarious habit before breeding. Inside the Park, they were rarely seen in flocks. Only after winter when the area started drying up, did they feed together and that too not as coherent flocks as that of the Pheasant-tailed Jacana. The possible reason for their not appearing as polyandrous may be the absence of long stretches of habitat. The habitats were isolated, small patches in which a female cannot hold more than one male.

PHEASANT-TAILED JACANA

Most of the data on the breeding ecology of the Pheasant-tailed were collected during 1988-89 from the Park. It includes aspects such as nest, egg laying, clutch size, egg morphometrics, chicks, breeding habitat and behaviour. In addition to this, some data on their breeding ecology were obtained from outside the Park during 1986-87.

Nest: A total of 40 nests were recorded as distributed among blocks B, D, E, F, K and L (Table 2). The water depth near the nest varied from 71 to 140 cm, average depth 98.4 cm (SD ± 15.9). Block F had the maximum number of nests followed by block K. Nests were located on three types of substrates, namely grass float (*Paspalum distichum*), grass mat (*P. distichum*) and *Ipomoea aquatica* plus *Nymphaea nouchali* float. Grass floats were decayed grass litter with or without live vegetation, whereas grass mats were thick, living grass rooted on the ground. Of the 20 nests where nesting substrate could be examined, 10 were on grass float and four on grass mat. The rest were on mat formed by different combinations of *Ipomoea aquatica, Nymphaea* spp., *Nymphoides* spp. and *Paspalum distichum. Hydrilla verticillata* were used as nesting material except when the nest was built on grass float.

Egg laying: Egg laying was observed once, outside the Park in a small village pond (Bancra pond) maintained for the cultivation of *Trapa natans,* but also containing *Ceratophyllum demersum* and *Hydrilla verticillata.* The female before laying eggs preened itself for a while and pulled up two or three twigs of *H. verticillata* and *C. demersum* which were present around the nest. After that the bird positioned itself on the nest with the cloacal region inclined towards the nest and kept its legs wide apart. The angle between the cloacal region and the nest surface was effected by bending the knee slightly and while doing so it ruffled the body feathers once and the golden feathers on the neck were kept raised. Then it started moving the head up and down rather rhythmically. It again adjusted the position of the

TABLE 2
DISTRIBUTION OF THE NESTS OF THE PHEASANT-TAILED JACANA INSIDE THE PARK

Clutch size	Number of nests in blocks							
	B	D	E	F	K	L	Total	Frequency distribution of clutches
5	0	0	0	0	1	0	1	0.034
4	0	0	1	12	4	1	18	0.621
3	1	0	0	1	2	1	5	0.172
2	1	1	0	1	1	0	4	0.138
1	0	0	0	0	0	1	1	0.034

legs increasing the angle between cloacal region and nest. This was followed by laying the egg within fractions of a second. The whole process described above was completed within two minutes. Soon after laying the female flew to a distance of about seven metres.

As soon the female left the nest after laying, a male bird (identity based on size) ran towards the nest, scooped up the egg in its beak and flew away. When it had flown about 6 m the egg was dropped into the water. This type of behaviour has not been reported earlier. Whether the bird intended to destroy the egg or shift the site was not clear. In all probability it was an accident, because egg shifting has been reported earlier in the pheasant-tailed jacana. Two different ways of egg shifting are reported: pressing the egg between throat and breast and dragging or rolling it over the matted vegetation while the male walks backwards (Ali and Ripley 1983) or holding the pointed end of the egg between the mandibles and dragging it backwards (Serrao and Shekar 1962). During the study period, a clutch of three eggs was found shifted from its previous location.

Clutch size: Although 40 nests of the Pheasant-tailed Jacana were recorded, information on egg production per nest is available only for 29 nests. Clutch size varied from one to five (average = 3.48). Clutch of five was rare and four was the most common. Block F had the maximum number of nests with 4 eggs (Table 2). The frequency distribution of clutch was calculated by dividing the number of nests with the clutch of different size by the total number of nests (Cochen 1988).

Colour and morphometrics of the eggs: Two types of eggs could be distinguished; one with a more or less perfect oval shape and the other with rounded top. The colour of the egg seems to undergo changes as incubation progresses. Fresh eggs were glossy-greenish bronze and became rufous-brown later. Eggs were not marked unlike those of the Bronzewinged Jacana. Morphometrics of 35 eggs of the Pheasant-tailed (Table 3) show that the size was almost the same as reported earlier (Baker in Ali and Ripley 1983).

TABLE 3
MORPHOMETRICS OF THE EGG OF THE PHEASANT-TAILED JACANA (N = 35)

Parameters	Maximum	Minimum	Mean	SD
Breadth (mm)	29.000	27.200	27.963	0.462
Length (mm)	40.500	29.500	36.779	2.170
Weight (g)	20.000	15.000	17.360	1.411

Breeding habitat: The breeding habitat of the Pheasant-tailed Jacana was assessed visually by recording the presence or absence of vegetation within a five metre radius of the nest. A total of 13 species of plants were present around the nest. Common among them were *Nymphaea nouchali, Nymphoides* spp., *Paspalum distichum* and *Ipomoea aquatica.* It is to be noted that *Nymphaea nouchali* and *Nymphoides* spp. had a very restricted distribution compared to that of *P. distichum* inside the Park.

In general, the breeding habitat of the Pheasant-tailed Jacana should have cover of vegetation patches of different species of aquatic macrophytes with intermittent openings containing submerged aquatic vegetation. The thick and expansive growth of any vegetation, especially *Paspalum distichum,* is unfavourable for their breeding.

To get a clear picture of the similarity of the Pheasant-tailed Jacana's nesting habitat, vegetation was quantified using 0.5 x 0.5 m chartered quadrat.

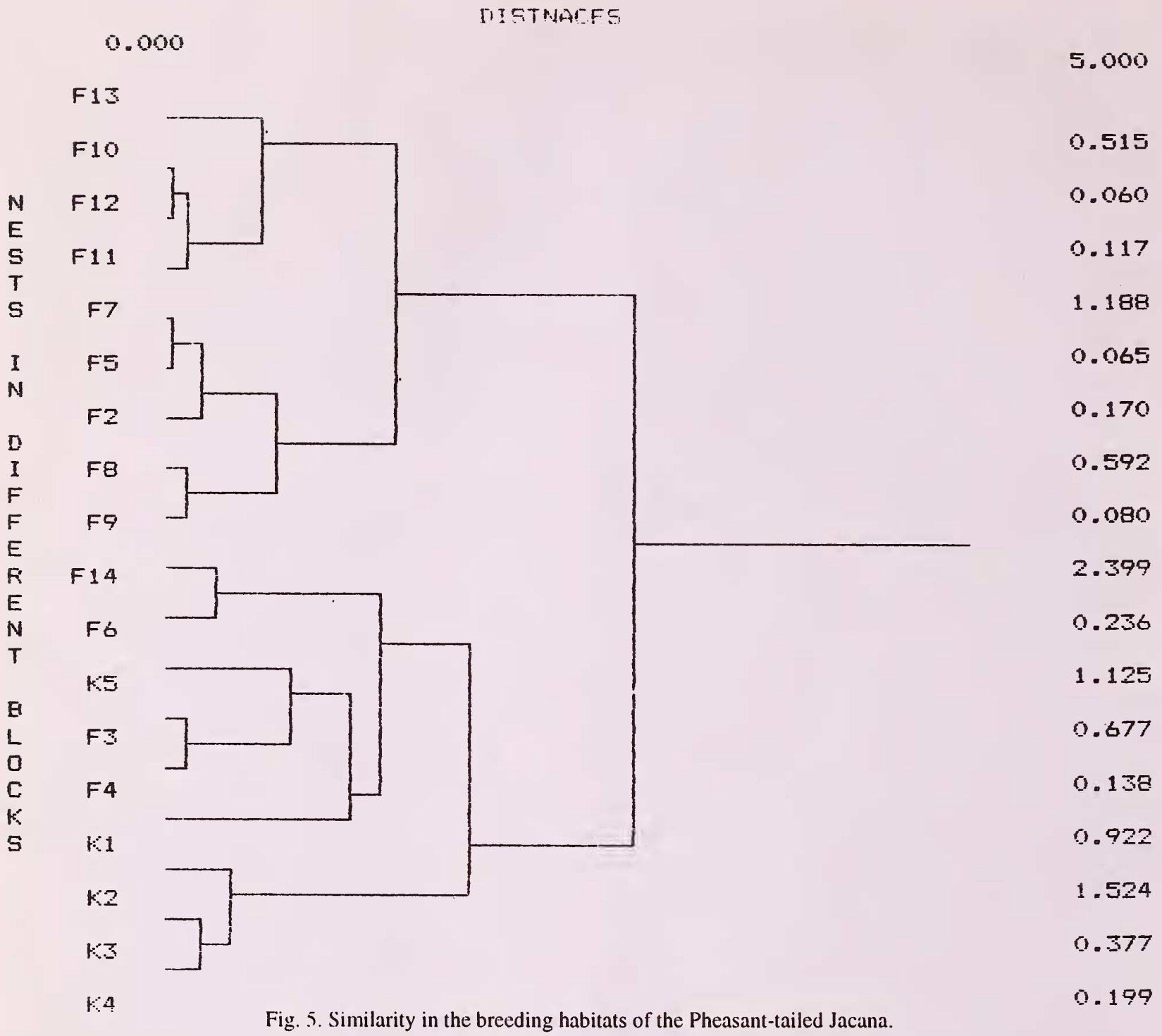

Fig. 5. Similarity in the breeding habitats of the Pheasant-tailed Jacana.

In all, 140 such samples were taken. These data were pooled together and a dendrogram was drawn using 1-Pearson correlation coefficient as the distance matrix and Ward minimum variance linkage as the clustering strategy (Wilkinson 1988). Almost all the nesting habitats clustered together at relatively lesser distance, indicating that nesting habitats are homogenous (Fig. 5).

Predation: The marsh harrier was the major predator of the eggs. Contents of most nests might have been preyed upon by them because marsh harriers were observed in more numbers in the blocks where the Pheasant-tailed were nesting in some numbers. Actual predation by marsh harrier was observed in four instances. As the four nests were close by, the predator could save searching time and hence, did not have to range over a large area. On one occasion marsh harriers were hunting in pairs when an incubating Pheasant-tailed Jacana from the neighbourhood came to the rescue of its neighbour. However, while both individuals of jacana were engaged in chasing away one marsh harrier, the other preyed upon the nest contents.

Breeding season of the jacanas: Both the species of jacanas commence reproductive activities with the onset of monsoon and subsequent flooding

of the area. The striking difference between the two species is the development of breeding plumage in the Pheasant-tailed Jacana and its absence in the Bronzewinged. The former species invariably arrives in the study area in breeding plumage after the flooding and hence, it was difficult to record the commencement of nuptial plumage.

Ali and Ripley (1983) gave the breeding season of the Bronzewinged Jacana as from June to September and further add that breeding commences soon after the setting in of the south-west monsoon. During 1986-87 nesting was noticed in the first week of June and during 1988-89 at the end of June. In the former year the hatching of eggs was completed by September.

The Pheasant-tailed Jacana bred inside the Park only once during the three seasons studied. Breeding commenced towards the end of June and was completed by September. Ali and Ripley (1983) recorded their breeding season principally as from June to September during the south-west monsoon.

Thus, the breeding season is the same for both species. Therefore, the reason for both the species not breeding together in the same location in large numbers is probably due to competition for resources, mainly food and space. However, the absence of any antagonistic behaviour by the Pheasant-tailed Jacana towards the pair of the Bronzewinged Jacana which nested very close is not supportive of the above speculation. Since it was only one instance, a definite conclusion is not possible.

Factors determining the breeding season

Biotic factors

Day-length: Day-length is a proximate factor in the timing of breeding (Perrins and Birkhead 1983). In both species of jacanas, the timing of breeding appears to be influenced by the day-length. Both of them breed with the onset of south-west monsoon. The breeding season coincides with the period when day-lengths are comparatively longer than during the approaching winter. This suggests that the day-length may be playing a role in deciding the timing of breeding. Moreover, both species finish breeding activity towards the end of September.

Temperature and humidity: The Pheasant-tailed and Bronzewinged avoid extreme temperature. Breeding occurs when the maximum temperature is between 33°C and 40°C, and the minimum between 18°C and 26°C (during 1986 and 1988 from July to October). The humidity ranged from 50% to 73% during breeding period of both species.

Rainfall and water input: The major abiotic factor in deciding the breeding season of both species is rainfall and the subsequent flooding of the Park from the waters of Ajanbund. This is evident from the failure of breeding in both species when the monsoon failed in 1987. During 1986, when the rainfall was 424.7 mm, the Pheasant-tailed failed to breed, whereas the Bronzewinged bred inside the Park. The factors responsible for their breeding are (1) the timing of rain, (2) rainfall and (3) water input from Ajanbund. Commencement of rain during 1986, 1987 and 1988 was almost the same. Rainfall in 1988 was higher than in 1986 and 1987 (Table 4). The water input into the system was minimum during 1986 and maximum during 1988 (Table 4). Despite the low quantum of water released to the Park during 1986, the stored water of the previous years made the total water availability in the Park in 1986 almost the same as in 1988. Thus, the failure of breeding in the Pheasant-tailed Jacana in 1986 may be due to differences in the habitat requirement and not related to the availability of water. The abundance of *Eichhornia crassipes* and *Ipomoea aquatica* provided ample nesting habitats for the Bronzewinged Jacana during 1986. But habitat with sparse grass and submerged vegetation, required by the Pheasant-tailed Jacana was rare and hence it did not breed. In 1988 when suitable habitat was available for the Pheasant-tailed it bred in good numbers. Therefore, although rainfall and water input are basic proximate factors in deciding the breeding season, actual breeding takes place only when the required breeding habitats are available.

Food: Both the Bronzewinged and Pheasant-tailed Jacanas were reported to feed on aquatic macrophytes and macroinvertebrate (Ali and Ripley 1983). Visual observations made in the present study,

TABLE 4
RELATION BETWEEN DIFFERENT HYDROMETEOROLOGICAL FACTORS AND BREEDING OF JACANAS

Year	Timing of rain	Rainfall (in mm)	Water input (in M m^3)	Breeding status	
				PJ	BJ
1986	June to October	424.7	0.017	nil	yes
1987	July to September	423.4	6.768	nil	nil
1988	June to October	614.2	13.730	yes	nil

while corroborating their findings, identifies some of the major macroinvertebrates consumed by the Bronzewinged Jacana. It includes (1) aquatic spiders (Arachnida), (2) *Cassida circumdata* (Coleoptera), (3) aquatic bugs, (4) *Ranatra fuscata* (Hemiptera), and (5) *Planorbis* sp. and *Lemnea* sp. (mollusca). Analysis of the stomach content of one dead Pheasant-tailed showed 70% of vegetable matter and 25% of molluscan shell. The coincidence of breeding season with the peaks in biomass production of both aquatic plants and macroinvertebrate suggests a strong relation between food availability and breeding in both species of jacanas. The failure of breeding by the Pheasant-tailed Jacana inside the Park during 1987 and their breeding outside the Park in a village pond can be explained by the availability of more food in the latter area.

Habitat: The breeding habitats of the two species were totally different. The Bronzewinged Jacana had abundant growth of *Eichhornia crassipes* and *Ipomoea aquatica* and other aquatic plants such as *Hydrilla verticillata, Ceratophyllum demersum* and *Najas minor.* The presence of such vegetation, especially the *H. verticillata* and *C. demersum* appeared to be essential for their reproduction. This is amply proved by the complete failure of breeding or reduced number of clutches produced when these plants were rare in the study area during the study period. The Pheasant-tailed Jacana requires habitats containing sparse grass (mostly *Paspalum distichum*), *Nymphoides* spp. and other hydrophytic plants. During 1988 the areas where they bred in good numbers inside the Park (Blocks F and K) were flooded with water consequently there was an abundance of scattered litter. In no other year did such a floating mass of grass litter occur inside the Park.

To study the role of different factors responsible for the difference in the habitat preference of the two species of Jacanas, macroinvertebrate, depth (1987 data) and vegetation (1988 data) were sampled from the feeding areas of the two jacanas and compared using non-parametric test. For the Pheasant-tailed Jacana, macroinvertebrate samples were collected only from Banera pond just outside the park (the species did not breed inside the Park). Vegetation was sampled from both Banera pond and from within the Park. For the Bronzewinged, vegetation, macrophytes and depth were sampled from the Park only.

The macroinvertebrate taxa present in the feeding area (inside the Park) of the Bronzewinged Jacana were Coleoptera, Diptera, Hemiptera, Odonata, Mollusca and some unidentified larvae. The major contribution to the total number of macroinvertebrates was by Mollusca followed by Odonata (Table 5). The total mean number of macroinvertebrates was 19.25 and the mean water depth 31.1 cm.

The macroinvertebrate taxa collected from the feeding area of the Pheasant-tailed Jacana in the village (Banera) pond were Coleoptera, Diptera, Hemiptera, Odonata, Oligochacta and Mollusca. The mean total number of macroinvertebrates was 40.3 and the major contribution to the total was by Mollusca (Table 5). The average water depth of this pond was 24.4 cm.

The feeding areas of the bronzewined inside the Park and in that of the Pheasant-tailed in Banera pond differed in water depth ($U = 72$; $P = 0.004$) and total number of macroinvertebrate. The taxa which differed significantly were Mollusca and Odonata (Table 5). Among these taxa, Mollusca were abundant in the Banera pond and where the Pheasant-tailed bred during this season. Hence, high availability of Mollusca is one of the important factor for the Pheasant-tailed Jacana while breeding as it

TABLE 5
DIFFERENCES BETWEEN FEEDING AREA OF THE BRONZEWINGED JACANA (PARK: n = 8) AND THE PHEASANT-TAILED JACANA (BANERA: n = 10) IN THE ABUNDANCE OF DIFFERENT MACROINVERTEBRATE TAXA DURING THE BREEDING SEASON 1987-88

	Bronze-winged	Pheasant-tailed	Mann-Witney U test	
Taxa	Mean	Mean	U Value	P*
Coleoptera	9.125	6.000	51.5	0.303
Diptera	0.375	0.300	45.5	0.533
Hemiptera	0.750	1.400	36.0	0.702
Odonata	1.625	0.200	75.0	0.001
Oligochaeta	0.000	0.100	36.0	0.371
Mollusca	7.000	32.300	0.0	0.000
Miscellaneous	0.375	0.000	55.0	0.039
Mean of total	19.250	40.300	5.0	0.002

Note: All the P values are rounded to three digits.
*P ≤ 0.05 is significant.

may provide the necessary calcium for the production of egg shells.

Though the water depth of Banera pond and the Park differed, it may not indicate a significant ecological difference as the selection of habitat for breeding depends on other parameters of the habitat also.

The vegetation was not listed by species, but according to leaf size, because it provides a more realistic picture of ecological requirements. The different categories of vegetation is explained in Table 6. The feeding area of the two jacanas differed significantly in the types of vegetation cover (Table 6). In the case of the Bronzewinged, submerged vegetation was abundant and grass was minimal; for the Pheasant-tailed open water and submerged vegetation (Table 6). Since the territory of each individual was a mosaic of different patches of vegetation, the individual abundance of different patches of vegetation types may not be the deciding factor but the proportional representation of them constituting a mosaic is important.

It is not necessary that the ideal breeding habitat of Pheasant-tailed Jacana should contain grass. For instance, at Banera pond there was no grass. There was only floating and submerged vegetations, namely *Trapa natans, Hydrilla verticillata* and *Ceratophyllum demersum.*

TABLE 6
DIFFERENCE BETWEEN THE FEEDING AREA OF THE BRONZEWINGED (N = 20) AND THE PHEASANT-TAILED (N = 14) IN TERMS OF COVER OF DIFFERENT AQUATIC VEGETATION DURING 1987-88

Types of	Bronze-winged	Pheasant-tailed	Mann-Witney U Test	
vegetation	Mean	Mean	U-value	P*
FLOVEGWLL	15.725	8.429	207.5	0.014
FLOVEGWSL	32.088	8.786	248.0	0.000
GR	0.200	21.321	9.0	0.000
OW	0.650	61.464	34.5	0.000
SUBVEG	65.100	0.000	273.0	0.000

*P ≤ 0.05 is significant.
Note: FLOVEGWLL : Floating Vegetation with large leaves. FLOVEGWSL : Floating Vegetation with small leaves. GR: Grass. OW: Open Water. SUBVEG: Submerged Vegetation.

Predation: Predation pressure seems to be one of the factors deciding the timing of breeding season in jacanas. Both species complete their major breeding activities before the population of migratory raptors builds up in the area. There are 23 species of migratory raptors and they start arriving from September. Their number reaches a peak in December-January. Finishing the breeding activity before the build up of the raptor population was reported in resident ducks too (Sridharan 1989). Since the chicks of jacanas are precocial, this type of adjustment in the timing of breeding is highly significant in maintaining the population. Birds breeding late in the season were susceptible to predation, especially by marsh harrier.

Nest site competition: Potential competitors for the nesting habitat of the two species of jacanas appear to be purple moorhen *Porphyrio porphyrio* and kora *Gallicrex cinerea.* Among these, the population of kora was very low during the period of study and hence, the pressure from them was insignificant. Both the purple moorhen and kora breed in thick growth of *Paspalum distichum* (Lalitha Vijayan, pers. comm.). Competition if it does exist, can be only between the purple moorhen and

Pheasant-tailed Jacana. However, one nest of purple moorhen about 15 m away from a nest of Pheasant-tailed Jacana was sighted and this suggests that there was not much competition between these two species. The two species of jacanas not breeding inside the Park in the same year during the study period does not indicate competition between them. Rather, it indicates that their habitat requirements are different.

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